A Transactional Perspective on the Practice-Based Science of Teaching and Learning

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1. Introduction

This chapter presents the perspective of "transactional inquiry" for understanding learning. In my understanding, this perspective is not strictly separable from the other two perspectives discussed at the Theorizing Learning Practice workshop—termed *participation/identity theory* and *dialogic theory*. Rather than being an alternative, the ideas have developed together in many researchers' minds, providing mutual support and value. In particular, I study and understand cognition within an activity theory framework, within which the notion of identity is fundamental (Clancey, 1997, Chapter 1; in press b; Lave & Wenger 1991; Wenger 1998). For the purpose of the workshop, I have focused on a transactional perspective, stressing the notion of inquiry that I have found to be useful in many settings, and aiming to bridge biological, cognitive, and social perspectives on learning. I provide an overview of the transactional/inquiry framework (Section 2), an analysis of three aspects of classroom inquiry (perceptual work, playful attitude and purposeful context; Section 3), and conclude with a proposed program of studies for practice-based science of teaching and learning, including research questions relevant to the classroom situation in the video (Section 4).

2. A Biological-Cognitive-Social Framework

In simple terms, the analysis presented here is a hypothesis, namely that understanding what happens in human behavior, and specifically where and how learning is occurring, is facilitated by considering the biological aspect of cognition.

To tie together the various threads of the present exposition: Most generally, my interest is to use a transactional perspective as an analytic tool to help reveal the neuropsychological (in most respects subconscious) processes that give cognition its character in different animals and individual people. In particular, relating emotion to conceptualization involves neurobiology (Damasio 1994). A transactional perspective facilitates understanding the structural and temporal nature of neuropsychological processes and relating them to learning and instruction (Clancey 1999 provides many examples). For example, a transactional perspective enables productively investigating humor in the classroom videos (Section 3.2), so we can better understand certain episodes neuropsychologically, socially, and in terms of instructional design.

In brief, a neuropsychological perspective on learning highlights (at least) the following aspects of cognition:

- **The perceptual-motor system** is not input and output to cognitive processes, but organizes and is organized by conceptualization, in a manner that is always simultaneous (a coupling mechanism), as well as sequential in behavior/experience over time (Dewey's [1938] view of *inquiry*).
- **The affective (self-regulatory) processes** by which emotional experience arises is not merely a reaction to a situation, but is part of the orienting mechanism for sense-making, a kind of pre-conceptual organizer (Bartlett's [1932] view of *remembering*).
- **Structural aspects of conceptual systems** (e.g., closure, islands, splitters vs. joiners,

verbal vs. visual preferences) surface in a variety of frequently ignored experiences that have been defined away as "not cognitive" or not functional (e.g., slips, humor, dreaming; what I have termed *conceptual coordination*).

In this introduction, I intend to present the transactional perspective well enough for beginning to uncover and analyze events in the classroom videos. I present some postulates from Dewey and Bentley's (1949) *Knowing and the Known*, plus a diagram from *Situated Cognition* (Clancey 1997b, "Transactional Experience" Chapter 9). I focus on Dewey's notion of inquiry, viewed as a kind of transaction, which is useful both to describe what is happening in the classroom we are studying and to prescribe a kind of idealized, project-oriented form of inquiry that might improve the students' experience.

2.1 Transactional Defined

In common parlance, a transaction involves some form of give and take. Buying something is perhaps paradigmatic: Two players have dual perspectives, one sells, the other buys; yet both give and both receive in the exchange of money and goods or services. In computer software, the paradigmatic example is a financial transaction, such as processing a check at a bank. One account is debited, the other credited; two numbers are adjusted. In these examples, an action involves two parties, both of whom must carry out their parts for the transaction to occur. The emphasis is on an exchange of something.

Another perspective, more common in psychology, focuses on how the players themselves are changed, as in this definition of transaction (Merriam-Webster 2002):

> **1 a:** an act, process, or instance of transacting **b:** a communicative action or activity involving two parties or things reciprocally affecting or influencing each other.

The change here, the influence, is *conceptual*, not merely changed possession of something

physical. In simple terms, Dewey would characterize the financial/database view as an *inter-action* (an action occurring between two parties, as emphasized by the hyphen). In contrast, a transactional view of purchasing, for example, would reveal how the personal relation of the seller and buyer have been changed: Is the buyer influenced to buy from this agent again? Adopting the inter-action view alone, analyses for automating web services focus on goods, services, and financial instruments, ignoring how the manner in which the transaction occurs influences the customer's loyalty, and indeed, whether they wish to *identify* as being this provider's customer (Clancey in press a). One could also consider how the transaction has influenced the seller's motivation to cater to the clientele represented by this customer.

Within a classroom setting, an inter-actional perspective focuses on players, materials, and processes as more or less given, and investigates what productive exchanges occur: Do students reveal misconceptions? Do they progressively exhibit better skills? Are problems solved efficiently? None of this is irrelevant or wrong *per se*; a transactional perspective examines differently how understandings and actions are developing within the action and hence shaping each other. The subject matter (note the substance metaphor) is not merely presented, exchanged, digested, and tested, but is (potentially) transformed in the understanding of the teachers, as well as the students. Perhaps more simply, the students are not simply presented with a situation that they must then understand, but their understanding of the situation is transformed during the learning experience itself. That is to say, the situation and understanding co-develop; the causal relation is dynamic, involving simultaneous, not only sequential affects.

Encapsulating the idea of dynamic activity, Dewey offers the very useful term, *inquiry*, which emphasizes that learning is an active, dynamic process of investigating, probing, reformulating, hypothesizing, examining, manipulating, deducing, theorizing, experimenting,

and so on:

> Inquiry is the controlled or directed transformation of an indeterminate situation into one that is so determinant in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole. (Dewey 1938, p. 108)

Using the online service example, the transactional perspective suggests viewing the customer's conversation with an agent (a person or program) as a process of inquiry. For example, a traveler may be planning a vacation and trying to determine what pleasing destinations are affordable. The character of the *problematic situation* (where to go, when and how?) changes as the traveler discovers concerns or opportunities that arise through availability, timing, enabled activities, and cost. A good travel service focuses not on making reservations, but on planning a well-formed journey by helping the traveler articulate and relate objectives and preferences. Indeed, a problem with today's online tools is that they are designed for a business transaction in the most limited sense, and not for carrying out a collaborative inquiry, through which both producer and consumer would learn and develop a relationship (Clancey in press a).

Readers of Dewey will recognize the relevance of a travel planning analogy, for Dewey's point about classroom inquiry was that the curriculum was just a map, a tool, not a destination. As an inventory of organized materials it serves as an *instrument*, promoting conversation in which learning on this and related topics will occur. The ordering and emphasis will depend on the circumstantial dynamics of the classroom. A question of interest is, to what extent is a particular classroom engaged in inquiry like the idealized travel planner I have described? Do

teacher and student co-construct the students' goals and interests as they discover together what the course materials afford?[1]

An inquiry itself, my analysis of the classroom represents what interests me today, looking at this material. Reflecting on my own methods, I show in Section 3 how inquiry might have occurred differently in the classroom we are studying.

2.2 Inter-action vs. Transaction

In contrasting Inter-action and Transaction, Dewey and Bentley (1949) were inspired by 1940s biological studies of the cell: "Manifestly, the subject-matter of behavioral inquiries involves organism and environment objects jointly at every instant of their occurrence, and in every position of space they occupy" (p. 130). They claim that the setting is always inherently "transactionally organic-environmental," so we must beware of the danger of specialized investigations that separate the system into parts to be understood independently, which they list as the mind, the psyche, the person, and the neural center.

Dewey and Bentley clarify their opposition to an inter-actional perspective, which is based on interacting properties of predetermined (atomic) entities. Thus inter-action concerns how traits interact, giving rise to observed properties, rather than how behaviors are improvised, emergent, and dynamic within a developing situation (affected by the person's manipulative probes and tentative actions):

> [The transaction perspective is] inquiry of a type in which existing descriptions of

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[1] This prescriptive notion of inquiry, often called "authentic learning" in the situated cognition debates (Brown, Collins & Duguid 1989), relates to an instructional design promoted as "cognitive apprenticeship" (Collins, Brown & Newman 1986).

> events are accepted only as tentative and preliminary, so that new descriptions of the aspects and phases of events, whether in widened or narrowed form, may freely be made at any and all stages of the inquiry. (p. 122)
>
> [Inter-action:] the various objects inquired into enter as if adequately named and known prior to the start of inquiry, so that further procedure concerns what results from the action and reaction of given objects upon one another, rather than from the reorganization of the presumptive objects themselves…. Transaction...proceeds with freedom toward the re-determination and re-naming of the objects comprised in the system. (p. 122)
>
> Inter-acting constituents are set up in inquiry as separate 'facts,' each in independence of the presence of others... [versus in transaction] no one of its constituents can be adequately specified as fact apart from the specification of other constituents of the full subject matter. (p. 122)
>
> Inter-action assumes the organism and its environmental objects to be present as substantially separate existences or forms of existence, prior to their entry into joint investigation…. Transaction is the procedure which observes men talking and writing, with their word-behaviors and other representational activities connected with their thing-perceivings and manipulations, and which permits a full treatment, descriptive and functional, of the whole process.… (p. 123)

A misconception to avoid here is that some human experiences are interactions and others are transactions. Rather, the invitation is to view all human experience as transactional,[2] and like any

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[2] The thrust of the argument in *Situated Cognition* is that expert systems and robots, which

analytic framework, use it as a tool for inquiry. Specifically, where does it lead in developing a practice-based study of learning and education?

One heuristic for adopting the transaction perspective in the present classroom video analysis is to focus on conceptualizations that are not about objects or people in isolation. After becoming familiar with the players, the layout, and the process, we can consider: *Relations* between people, how they are conceiving of their *persona-activity* (who are they being now?), and *norms* they express and enforce. To bring out the neuropsychological aspect of these conceptualizations, I focus on the interplay of perception, emotion, and conception visible in the classroom video (Section 3).

2.3 Coupling and Sequential Events

The transactional perspective can be useful for talking about and visualizing the relations between emotion, perception, conception, and action as we study classroom episodes. In particular, my approach to situated cognition has been to emphasize how these aspects of cognition are co-determined (functionally and physically develop together). The main ideas are summarized here (see Clancey 1997b for elaboration and references):

- Categorization occurs on two levels of neural organization: perceptual and conceptual.
- Conceptual categorization is higher-order (composed of other categorizations

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fundamentally operate by manipulating descriptive models of the world and/or their behavior, do not have transactional experiences because they do not conceptualize at all (and hence are not conscious, which is to say they do not have experiences). Arguably the only transactional aspect of today's computer systems occurs through "neural networks" that develop new perceptual categories coupled to motor actions (Clancey 1997b, Chapters 6 and 7).

hierarchically and serially) and always temporal (either sequential or simultaneous, aka *structural coupling*).

- Categorizations are constructed (develop) from previous categorizations; thus categorizing is in some respects an activation process.
- Perceptual categorizations involve features, which are themselves not given, but learned.
- Information is not given (substance entering the organism, an input), but categorizations forming within actions.
- Perception, conception, emotion, and action are mutually constraining, i.e., they arise together, co-develop, determine each other.
- Conceptualization of context (my situation now) and activity (what I am doing now) are mutually constraining.
- "Seeing as" and figure/ground transformations are fundamental to visual conceptualization.
- Describing occurs in conscious (speaking, writing, silent speech) behavior, not internally as (timeless) inferences between actions.
- Descriptions (most generally, models of the world) are instruments within an inquiry activity.
- Descriptions do not act on descriptions in the human brain, in the manner of a logic calculus; descriptions are perceived, reconceived (interpreted), and reformulated through new conceptions—the activity of comprehension is not text manipulation but conceptual recoordination.
- Deliberating is an inherently conscious activity occurring within inquiry, as sequences of representing (in imagination or the shared world) and reflective comprehension and

reconsideration—not occurring subconsciously between thoughts.

Summarizing from Dewey's perspective, thoughts provide the materials for inquiry, they are neither its atomic elements nor its molecular products:

> Perceptual and conceptual materials are instituted in functional correlativity with each other, in such a manner that the former locates and describes the problem while the latter represents a possible method of solution. Both are determinations in and by inquiry of the original problematic situation whose pervasive quality controls their institution and their contents... As distinctions they represent logical divisions of labor... The idea or meaning when developed in discourse directs the activities which, when executed, provide needed evidential material. (Dewey 1938, p. 111-112)

In my understanding of inquiry, I have also reformulated Schön's (1979, 1987) analysis, itself adapted from Dewey, to fit terminology more commonly used in cognitive science. I believe this framework is a practical starting point for applying a transactional perspective in the classroom, which is to say, to study learning as inquiry:

> Schön's framework requires a shift in perspective: We view descriptions as *created in conscious behavior*—in imagining, speaking, writing, drawing, not manipulated in a hidden, cognitively impenetrable way inside the brain. In its primary manifestation, human memory is the capacity for automatically composing processes of perceiving and behaving, including creating representations (doing, adapting). In cycles of such behavior, what James called the "secondary" aspect of remembering, we *model* what we have said and done before (framing, history-telling) and engage in a meta-activity of modifying our language, tools, facilities, and social organizations (designing). (Clancey 1997b, p. 216-217)

I visualize these phases—doing, adapting, framing, history-telling, and designing—as not linear-sequential so much as iterative and simultaneous (conceptualizations occurring at the same time and influencing each other). Figure 1 shows behavior as cycles of perception-action of two people, with different levels of transactional influences. The key idea is that speaking, visualizing, and transforming things in the world occur *over time, as activities,* involving both neuropsychological and interpersonal coordination (Clancey, 1997, pp. 218-219).

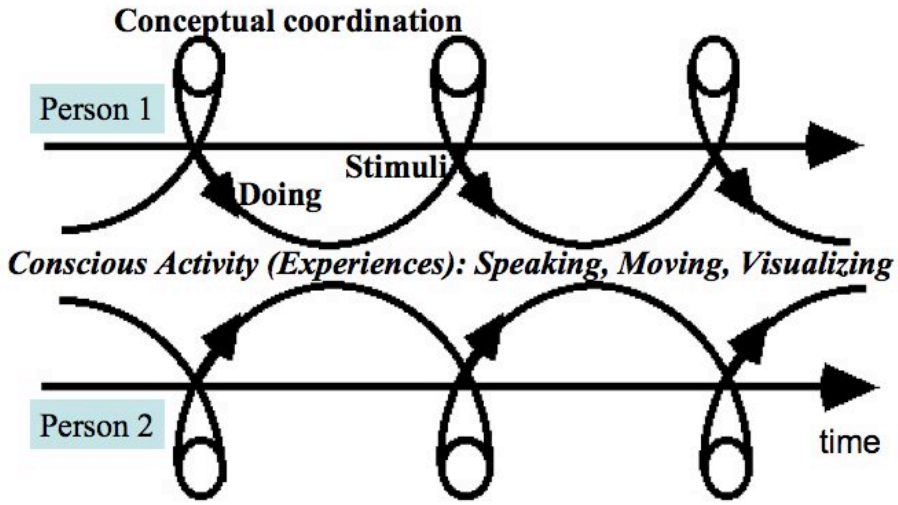

Figure 1. Transaction of two people (e.g., where one person's actions affect how another objectifies [chunks] and interprets his/her own past actions) occurring simultaneously with neuropsychological coordination (shown as circles), that dynamically relates, adapts, and recomposes perceptual, emotional, and conceptual organizations.

(Adapted from Clancey [1997] Figure 9.4)

The essence of "transactional" is to not view stimuli, intent, or visualizations as somehow packaged up and moving along in time to create responses, plans, objects, etc. But rather what we often view as causal results of mental activity, such as emotions and inferences, are both reorganizations of experience (present and perhaps distant past) and orientations for the current activity (which involves perhaps simultaneously speaking, drawing, and visualizing). Thus, from

a traditional cognitive modeling perspective, the notion of transaction is a non-linear conception of causality. Rather than "stimuli causes response" or "emotion is a reaction to a situation" or "conception interprets a perception," we have responses that change stimuli by movement, emotions that orient our conception of what the situation is, and conceptions that change what objects or relations are perceived. Even this statement is still too linear, for it just admits a feedback or bi-directional influence. But I believe it's a good start for knowing what to look for, as we study the classroom video.

Nobody contests that learning involves neurological processes; the question is how is the biological nature of learning manifested in a classroom? I show in Section 3 that neuropsychological constraints and influences are especially salient in the perceptual work of creating and interpreting graphs and the humorous interplays of the class sessions we are analyzing.

2.4 A Meta-Methodological Reflection

In summary, the essence of a transactional perspective is to beware carving up the world into objects with properties and then studying them alone or in interaction. Accordingly, there is no one way to break up the whole system to define "the transaction." In particular, my own analyses are contingent constructions: I have made selections from the video for a variety of reasons ranging from the time available to me, what I believe to be of interest to the research community, my past experience in analyzing classroom videos, what engages me today as dramatically interesting, what the camera position reveals, and so on. I have been charged with presenting a particular perspective, so I don't focus on identity, participation, discourse, etc. I am presenting materials that in some important sense do not pre-exist my analysis, in the sense that they are carefully arranged selections; laden with my own emotional manner of ordering my life

into a world of objects, people, and relationships; and described in a rhetorical fashion in the genre of a presentation, an analysis with hopefully new findings, and recommendations. It is not my purpose to do a meta-analysis of the methodology of studies of learning, but to present a particular perspective that embodies such a methodology. Dewey states this aptly[3]:

> Selective emphasis, choice, is inevitable whenever reflection occurs. This is not an evil. Deception comes only when the presence and operation of choice is concealed, disguised, denied. Empirical method finds and points to the operation of choice as it does to any other event. Thus it protects us from conversion of eventual functions into antecedent existence: a conversion that may be said to be the philosophic fallacy, whether it be performed in behalf of mathematical subsistences, esthetic essences, the purely physical order of nature, or God. The present writer does not profess any greater candor of intent than animates fellow philosophers. But the pursuance of an empirical method, is, he submits, the only way to secure execution of candid intent. Whatever enters into choice, determining its need and giving it guidance, an empirical method frankly indicates what it is for; and the fact of choice, with its workings and consequences, an empirical method points out with equal openness. (Dewey 1958, p. 34)

In particular, I may sometimes appear to be adopting a folk view of research, as I put forward excerpts and interpretations as if they are objective facts that pre-existed my interest and are unchanged by my thinking, writing, and working with others on this project. But this may itself be a reflection of how neuropsychological constraints affect analytic practice.

Referring back to the logic of inquiry paraphrased from Schön, it appears reasonable to

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[3] I am grateful to Jim Garrison for pointing out this passage.

hypothesize that the sequential and compositional nature of categorization affects how we order experience into objectified things, sequential stories, and linear causal models (Clancey 1999). Were I to self-consciously apply the transactional perspective to critically examine my own analysis as it unfolds, I would stumble over myself, and be ineffective, precisely because as I approach these materials I need to chunk, label, order, sequence, and causally rationalize in a certain way—because that is how the simultaneous, parallel aspects of activity are effectively realized in personal experience, in stories, and in our research communications.[4] Although my style is deliberately narrative, we can later reflect on what this effort itself reveals about the nature of inquiry: "Transaction…represents that late level in inquiry in which observation and presentation could be carried on without attribution of the aspects and phases of action to independent self-actors, or to independently inter-acting elements or relations" (Dewey and Bentley 1949, p. 121).

Further, this reflection suggests that the transactional perspective may be difficult for the classroom participants to grasp. The ideas of coupling and dynamics may not have any apparent value at first, because it requires an understanding of problems and solutions that is not simply packaged into procedures. Teachers may prefer and even require linear causal explanations and

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[4] On revising an early draft, I removed all colloquial uses of the word "interaction." In most cases, I now say "episode," which has the advantage of indirectly implying that I have bracketed the video stream and am viewing the resulting sequence as being a unit with certain properties. In other places I say "participation," e.g., in referring to the teacher's participation style (manner of being involved) during the students' presentation of graphs to the class.

methods if they are to gain anything from our study. And at a certain level, this restriction may carry over into the genre of our research writings and workshop presentations.

3. Aspects of Inquiry: Perceptual Work, Playful Attitude, and Purposeful Context

Before writing the analysis that appears in this section, after several days of reviewing the materials, I annotated the two available segments with Tanner's group (including Jessica, Erica, and Kevin). The first is from March 13, as they design the graph with LS. The second is from March 15, as they present another group's graph and comment on their own. I then summarized patterns that interested me: Most strikingly, the graphs vary more than I would expect in a classroom exercise. The class converses at some length about the graphs, both with and without teacher direction. The students clearly make sense of the markings, learning why graphs have keys and thus that they may have different designs. The students also explain graphs by attributing beliefs to the designers, recognizing that different groups understand and think in different ways ("To them ours didn't make sense, and to us theirs didn't make sense"). Contrasted with using textbook conventional designs, the students' graphs provide interesting material for the class to investigate.

On the other hand, based on fidgeting and how often many students appear bored, something appears wrong in how the exercise is designed or being carried out. Further, the teacher's enthusiasm for each graph made me confused about the measure of value; is this a brainstorming exercise where creative variation is highly valued?

With many possible interesting topics to explore, I have chosen to elaborate three themes from a transactional perspective:

1. **Perceptual Work: Putting out representations into shared space.** The graphs are

representations that are manipulated, reperceived, reinterpreted, and adapted in design and presentation activities. But the teacher's virtual modifications of the graphs reveal that imaginary objects may also be shared.

2. **Playful Attitude: What does laughter and play suggest about classroom practice, relevant to designing educational activities and evaluating learning?** The video record enables us to learn a great deal about a group (Erica, Jessica, Kevin, and Tanner) facilitated by LS. Studying the nature of humor in this episode reveals the value of transactional perspective, specifically in understanding and designing facilitation.
3. **Purposeful Context: The classroom exercise and teacher's lesson plan focuses on math as inherent, abstract properties of graphs, as opposed to framing the graphing as an inquiry about plants.** The confusion about which graph shows "spread" better suggests a problem, which could be explained by the "decontextualization" of the list of numbers (Collins, Brown, & Newman 1986; Brown, Collins, & Duguid 1989).

3.1 Perceptual work

Perceptual work is a good example of Dewey's point about the active nature of getting information: Parsing the data chart (called a "graph" in the class), orienting the presentation sheet, understanding graph notation (what's a symbol, what's a design?), relating the graphs to each other. As demonstrated by Schön (1979; 1987) and Bamberger (1991), inquiry often involves constructing representations by perceptually segmenting and manipulating physical objects.

3.1.1 Interpreting visible artifacts

The plant data sheet provides an obvious example of perceptual reinterpretation at work. Each

word of the title at the top of the sheet is apparently aligned with a column: "F-6 Day 19 Data in mm" (Figure 2). The students picked this up: Dana says, "I don't get it. At the top it says F6, and then day, and then day 19." This reveals that she has learned a convention for perceptually grouping a chart into columns with headers. Indeed, one could easily make a transcription error in taking 19 to be a number (though it would be the smallest).

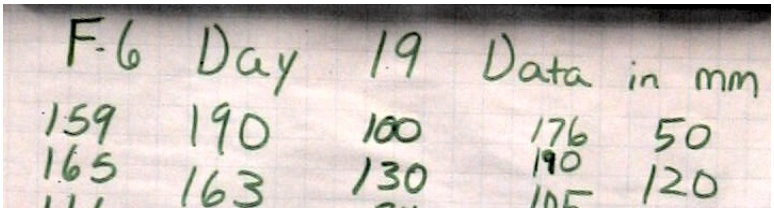

Figure 2. Top of data chart prepared by the teachers, combining plant heights measured on Day 19; from two experiments, F-6 and HL

Another problem is that the 190 below Day might be read as 110 (explaining Tanner's remark on March 15 that they had one too many 110s). Further, the chart is said to combine data from two experiments, but HL is missing from the title—further implying perhaps that F-6 designates the column with data from that particular experiment. (Indeed, for all we know, this was the original meaning, and later the data were combined.)

Another recurrent perceptual transformation is how empty space takes on meaning (Schön 1979). For example, Katie L. notices that using a coordinate system (scale for X-axis) results in white space where there is no data—and this empty space has meaning:

> 0315-12:13 Katie L: I think probably this graph (the binned one, is better), because they still leave the spaces there, even if there's nothing there. So you can really see how spread out it is. You can see how much space there is.

Another striking example of perceptual work is how physically turning a representational artifact may lead us to interpret it differently:

> 0315-19:55 Isaac: They had the one column on the Y axis and the one digit on the X axis. So like 121

would be there. You'd find 120 and go down to one.

Teacher: So you'd like it if the graph was turned, maybe? (turns graph 90 degrees) So we have the tens going along this way, and the Xs going up, like that?

Isaac: Well, I'm not sure.

Teacher: Because then it looks more like what another group already did.

It is a strange idea, when you consider it, that how we see a representation depends on how it is oriented with respect to our eyes.[5]

3.1.2 Sharing imaginary representations

In the available video, the most interesting example of imagining representations occurs as the teacher leads the group to compare the graphs and imagine extensions (e.g., to include the number 255):

0315-10:33 Teacher: I'm wondering which graph would show the spread better? Let's ignore 255 for a minute and assume it was 555. Does that feel like quite a bit different than 255? That would become a much bigger spread if we included that number? So let's pretend this is 555. Would this graph help you see that that's more spread out? Is there a graph up there that might help?

The teacher proceeds to pick a chart and asks about putting "555 right here on the end?" And then goes to another, asking, "What if we dit it on this one here, 555 here (gesturing)? So having a scale down here would help you see the spread better?" He asks Will "How far would I have to keep going to get to 555…. What would the scale say when I got to it, to that far?"

Again, they are sketching *virtual graphs* (e.g., extending out and saying what it would look

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[5] Similarly, AI researchers in the late 1970s argued about the virtues of hierarchical trees and "blackboard levels," without recognizing that they were congruent representations—just draw bold lines across each level of the hierarchy, then add more lines to show evidence relationships.

like). This becomes part of the portfolio of graphs on the board, these imagined extensions. The teacher is pointing at one graph (d), but extending the bins (graph #4) (Figure 3).

> 14:40 Teacher: So we'd have to continue 550 to 559 and there would be a 555 right above it. (pointing at the empty board)

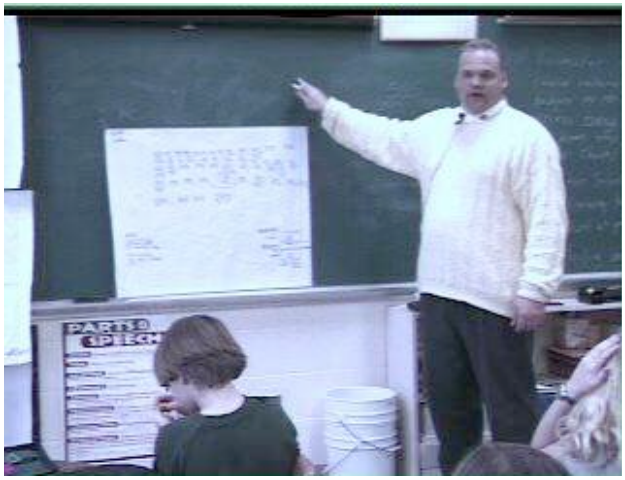

Figure 3. 0315014:51 "A 555 right above it."

> Then that would look pretty spread out, wouldn't it? Does anybody disagree that that would look spread out? If we, if you had a scale? Whereas on this one, all we'd have to do is erase this (2 of the 255) put a 5 there, and just leave it. So maybe this one doesn't help you SEE how spread out it is, as that type of a graph (gesturing to the bin). And like Isaac said, as long as you have a scale on the bottom (gesturing in and out to show range/spread concept) that helps people determine how spread something is. Katie?

Now a 45 second conversation occurs with half a dozen players, as the nature of a scale is further emphasized. More imagined objects and functions are constructed:

> Teacher: Yeah, they put a scale on it! So 500, what do we have here, 250? So 500 would be twice as high. So it's gonna be up there somewhere. (Holds the ruler up above the graph, literally extending the scale with the ruler's markings.) So the scale helps you see how high it is. (pause) Is that what you...?
>
> Katie: I think that one (bins) and that one (Y axis graph) are best.

In summary, the meaning of the graphs has now been transformed several times: By the groups working with each other to understand the designs; by the presentation with the class probing; and by the teacher's comparing graphs and extending them. They've created a representational world, an ecology of representations, which now includes graphs as artifacts plus imaginary modifications. These are put out by gesturing; they exist now as numbers and lines in a shared space with agreed properties, which is totally imaginary!

The graphs are no longer viewed as just marks on paper, but tacitly as including other (un-written) numbers, and as having a ruler-like scale that defines an axis. The meaning of the graphs for the students now combines their individual intents in their groups as they designed a graph, with the larger issues raised by seeing other approaches and comparing what you can see and what you can change. The overall activity has taken on some of the transactional characteristics highlighted by Schön (1987) in his analysis of architectural sketching, where there is an interplay between preconception of a design, an initial sketch, a re-interpretation of (perhaps serendipitous) markings, and an adaptation of the design to better fit aesthetic and practical constraints.

In considering the notion of fixed, pre-determined objects versus those whose character emerges in activity, we might contrast the teacher's view of concepts like "spread," and the students'—do their own graphs take on new features as they discuss spaces, for example, and how to talk about what is typical (e.g., Tanner's arms in the air, as he shows the middle of the graph)? Here I am reminded of Schön's (1979) analysis of the paintbrush inventors, discovering that spaces between bristles are functionally channels for the flow of paint. Thus something that is perceptually ignored as "blank space" or devoid of content becomes a feature with describable properties and a causal history that ultimately relates to the design of the paintbrush.

3.2 Playful attitude and humor

In this section I explore the hypothesis that we can understand humorous activity as transactional, in contrast with the idea that something or someone being "being funny" is a trait of a story (joke) or person.

3.2.1 "Reflex" vs. Intentional Humor

My objective here is to illustrate the social aspects of humor in this classroom, and perhaps accordingly enrich our understanding of the experience of learning, especially in a group setting. In particular, I suggest that including humor in a theory of conceptualization will better reveal the functional role of emotion and thus how it should enter into a theory of instructional design.

First, I distinguish between "reflex" laughter (and giggles or smiles) and intentional actions, which are willfully humorous or playful. The latter range from putting on a happy face (Jessica's smile for LS) to Tanner's gestures in the group, and his flight back into the room. I use the term reflex advisedly, to refer to a response not mediated by inference. Although uncontrolled, it is conceptually organized and not to be confused with non-cognitive nervous system behaviors.[6]

A good example of reflex laughter is when the teacher mispronounces "bin." At 0314-29:01 the teacher says, "You can put things into a bin" (sounds like ben; he gestures). At 29:03 a weak voice says, "bin?" He spells B I N, and someone says, "I thought you said Ben!" Then at 29:09

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[6] Glenn's (2003) conversational analysis of laughter as a social interaction also distinguishes between reflex and intentional laughter, which he characterizes as two types of analysis, physiological and social. I am distinguishing instead between two kinds of experience with different temporal and attentional characteristics. Perhaps more importantly, I am viewing the episodes more broadly in terms of *play*, and not concerned with laughing *per se*.

the class laughs as he corrects his pronunciation. This is a familiar reaction in a group when someone makes a mistake. The laughter seems to relate both to the conceptual breakdown (the difficulty of recognizing the mispronunciation), as well as the social relation (Provine, 2000; Glenn, 2003). The reaction is quick and subconscious. Overall this laughter suggests a good rapport between the teacher and the class, and affirms a norm for handling slips, which are unintentional mistakes in someone presumed to know better. (It would be absurd for someone to now lecture the teacher on the difference between the two words; misunderstanding wasn't the nature of the error.)

Another example of a reflex laugh occurs when a girl has read out the average written on a sheet as a number greater than a million (0314-23:33):

> Teacher: Does that make sense?
>
> Unseen boy responds: "If you look closely it's 133 POINT... "
>
> Girl: "That's a point?" (turning to the boy who wrote it)
>
> Boy: Yes. It IS (laughs).

Laughter may acknowledge that perhaps the mark is an unusual decimal point, making this a self-deprecating response—a way to handle conflict. Later, a girl laughs acknowledging that there is something strange about her "stair graph":

> Girl: We were thinking about different graphs, that we could make like bar graphs and stem and leaf and stuff. And we didn't really know how to do that, so we started to think up new ideas that would work.
>
> Mitch: You wanted it to act like it's a ratio graph? Because I've never seen that one before.

This graph is odd and the class is apparently entertained by it. They are perhaps not sure what to think about it. It's interesting, but is it good?

In contrast, joking and playful behavior occur more deliberately (with attentive control), *as a manner of carrying out an activity*, expressing an attitude that persists over several minutes at

least. By the transactional view, a first-order characterization would be that the audience and the humorist co-create the humorous experience or event. Thus Tanner plays to the class (the comedian plays into the crowd), as they anticipate his being funny (as he anticipates their appreciation). Similarly, the "Ben" event starts as a few students' reaction, but becomes more of a class-wide experience as the students hear each other and the teacher responds.

Considering humor is helpful and revealing because it focuses our analysis on behaviors or even better, *experiences*, as the objects of inquiry, rather than only what we normally view as *things*: groups, individuals, graphs, and terms. Also, we might consider attitudes, as revealed in an individual's tone of voice, gestures, gaze, and participation. Can we relate participants' attitudes during the *presentation* of the graphs with their experience when the graphs were invented?

3.2.2 Playful behavior as mutually constructed

When we start looking for humor in the video, we notice that term applies to interpersonal relations, activities, and particular actions: Jessica and Tanner have a relationship full of humor; their group jokes around while making the graph; Tanner evokes laughter several times during the group's presentation. In these activities, the humor involving Tanner indicates his playful attitude. This is most obvious in his group's graphing activity, but also both he and Jessica make playful full-body gestures at the front of the room. Tanner, at least, seems aware of himself as being visible. He is "presenting-to" not merely reciting or standing. He doesn't merely act, he "acts-for"—he conceives of his activity in relation to an audience (indeed, this is common to artistic activity, as a variation of the tacit evaluative conception of all activity as relating to norms).

This suggests another useful analytic characterization: The participants' conception of What-

I'm-Doing-Now (WIDN, see Clancey, 1999). At times Tanner is evidently showing off, pestering, and flirting. His whistling while LS is speaking to Erica and Jessica may be interpreted in several ways: He is setting himself apart from "the girls" (LS is helping them; he and Kevin will wait it out); he is also arguably rejecting LS's intervention and apparent control of the group. But to the point, Tanner expresses himself not by explicitly disagreeing or seizing control himself (LS outranks him greatly), not by going away (not possibly an option), and not by totally ignoring them. While appearing to literally wave LS's participation away with his sheet of paper (0313-9:00), he also interjects relevant remarks, showing that he is paying attention. His whistling therefore appears more like *counterpoint* to LS than drowning her out, illustrating the notion of transaction or coupling of behavior.

An inter-actional perspective would say, "Ah, Tanner is a playful boy. He is difficult. Place him into any group and he will be the clown." It may be true that a pattern of sorts will occur, but the *character* of the playfulness is open to change. This is why it is helpful to see Tanner during the presentation, where he is obviously engaged and even something of a leader. We see that the class as a whole (apparently) relates to him as humorous (was the teacher smiling?) and he is even self-deprecating.

LS comments in her notes, "The boys do a lot of playing around, especially Tanner, and really need to be pushed to work on the problem." However, she never admonishes them in the segment available to us. LS is pushing only in the sense of orchestrating the entire graphing process. Was this pushing Tanner away from the table? A transactional view asks how LS's behavior and Tanner's were co-determining. Just as we wouldn't say that Tanner is necessarily requiring guidance, we wouldn't say that LS is necessarily over-controlling. Together, they form an *ensemble* (with Jessica, Erica, and Kevin). The ensemble is improvising their parts, as they

are inventing a graph, reflecting on the developing design, their progress, their behaviors, and feelings about each other.

Figure 1 is an attempt to visualize how two people are mutually constituting their experience. While doing something (even sitting still), each person is perceiving what the other is doing, noticing especially how the other person conceives of what either has said or done before. Some remarks will perhaps be pivotal, but it is difficult to break this into a linear-sequential give and take. Giving and receiving occurs simultaneously for all players, and is multidimensional. Tanner whistles while LS is orchestrating; at the same time he is paying attention to what they are doing while moving around in a way that distracts the others. Oddly enough, each time he is challenged ("Tanner!") he responds not with something yet more boisterous, but with a productive remark about the work. He is always engaged, as I show below in a more detailed analysis. This conceptual ability to blend multiple activities, being tacitly aware of different threads, allows Tanner and the girls to mix commentary on what is happening, while remaining involved with LS. And thus I stress again that the nature of activity, as transactional, reflects the neuropsychological nature of conceptualization, as a coordination process that is simultaneously compositional (with blending of conceptual), sequential, parallel (in creating and relating perceptual features and categories of different modalities), and emotional.

3.2.3 Playing in the March 13 design session

During the March 13 design session, Jessica three times rebukes Tanner with a soft, but direct look and statement: "Tanner." Erica rebukes him also three times, but more insistently: "Stop, Tanner. Tanner!" and "Don't, Tanner!" These interventions are short interruptions, which more resemble juggling attention, than shifting contexts. Tanner is still engaged with them, and their reaction a means of sustaining this relation, while simultaneously working with LS. The relation

is mutual, for Tanner's noises and gestures are perhaps not deliberate disruptions, but a kind of commentary on the on-going LS-orchestrated activity. Tanner is part of this activity, as indeed the activity for Jessica and Erica becomes a blend of attending to and relating with both LS and Tanner. Put another way, Tanner's playfulness is not necessarily a mark of disengagement, but rather *a way of being part of what is going on.* He has not walked away, he is not attending to anything else. He is observing and oriented toward the graph and the conversation with LS. His behavior is a *playful manner* of participation, a mode or style.[7]

Examination of this episode with only the rebukes and Tanner's remarks shows that he tends to say something just after a rebuke, and is always apparently engaged in the work.

22:48 Jessica: Tanner...

22:52 Tanner: There's 46.

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[7] This analysis is supported by theories that humor involves sustaining "mutually contradictory frames of interpretation" (Mulkay, 1988, pp. 32-35, cited in Glenn, 2003, p. 21). In contrast with the view that laughter involves a kind of physical relief of tension when attempting to relate incommensurate frames, a *humorous attitude* is an emotional means of keeping oneself oriented, while otherwise inconsistent conceptualizations are simultaneously active. This follows from Bartlett's (1932) analysis of the role of attitude in the action of remembering. Also, viewing the episode as a *communication*, Bateson's (1972) analysis of play suggests that "The message 'This is play' establishes a paradoxical frame" (p. 184), in which "These actions, in which we now engage, do not denote what would be denoted by those actions which those actions denote" (p. 180). Thus, Tanner's actions such as waving the paper in LS's face are not an attempt to disrupt the group and end the task, but perhaps to instill a different manner of working or relating.

LS: I'm not making myself very clear, am I?

Jessica: I don't know what you're talking about actually (laughs)

LS: Do you get a sense of what I'm talking about, Jessica?

Jessica: That's Erica. (they laugh)

25:00 Tanner: Because you know, they don't listen (pointing to girls)

26:04 Tanner: Oh, I get it, so there'd be...

Tanner: So you'd write one through ten?

(More banter with Jessica)

27:20 **Tanner: "Don't write anything yet"**

28:20 Jessica: Tanner, stop it.

Tanner: "you just wrinkled the paper" (with a mocking finger. They all laugh visibly. Tanner looks at Kevin and says something to him. Jessica is obviously happy and looking at Tanner for several seconds. Kevin is pointing, saying something. Clearly they are engaged in one activity.)

Erica; Stop, Tanner... Tanner! (more insistently)

(LS corrects 109 to 119, 119 to 129)

29:30 Tanner: Nooo, that's not what we are doing though... (Explains they are starting at 1 to 9)

Erica: No wait, it doesn't even go that far. ... Tanner, Tanner!

(LS says something)

Tanner: Yeah, we should start at 30 to 39.

31:-- (Tanner is waving a sheet of paper in the air and whistling; Jessica is watching with eyes askance, and says very simply "Tanner." then whispers something. Then he plays with his arms behind his back and his head near the table going something like "Whoa, whoa whoa"; Jessica says again "Tanner.")

32:00 Erica: We d:on't w:ant it tha:t w:ay (drawn out) because we don't want it that way. (looks at camera) Don't, Tanner! (looks at him smiling. Now he makes some fooling gesture with Kevin.) Tanner: (referring to the girls) **"Wrinklers!"**

(They laugh as Erica breaks her pencil drawing in her notebook.)

Tanner: You're pretty (slick).

The rebukes indicate an attempt to define a norm, and includes particularly a constraint not to mess with the paper, which is to be the presentation copy. “Tanner!” could be interpreted as a comment as well as a call, bringing him in to the work. Again, it could have been different: The girls might have ignored him or indeed LS might have said something. But the expressions and tone suggest more an appreciation of his play than being disturbed. For indeed, controlling propriety and asserting the norms is mutual and playful, as Tanner says “You just wrinkled the paper!” and later calls the girls “Wrinklers!” The rebukes—from both sides—are part of this activity of working with LS and preparing a graph for presentation. Again, these remarks seem to be inherent, not interruptions, but a character of the work activity itself. That is to say, this is how they do their work. This is how they carry out the assigned task. *This is their practice*, relating to each other in playful rebukes and interruptions. Indeed, one might say that the proprieties of the classroom, norms such as not to wrinkle the paper and to attend to LS, have provided a resource for relating to each other. This background becomes a setting for Tanner to play against, for them to express how they feel about each other, to explore and develop these emotions. Thus the gestures and drones are figures that tacitly acknowledge the background of the norms. One might analyze further to inquire about the structure of the play, its phases and transitions as people come in and out of activities.

Transactional figure-ground relations—found at all levels of cognitive activity from perception through conceptual classification to interactive style (Clancey 1999)—seem to be a fundamental organizing aspect of human experience. The formation of categories through figure-ground relations apparently stems from the physical nature of the neural system. In the next subsection, I attempt to relate these analytic perspectives.

3.2.4 Relating the biological, cognitive, and social perspectives of humor

In studying the functional aspects of humor, we are confronted with a phenomenon that obviously has biological, cognitive (conceptual), and social aspects. When researchers have studied "learning," it has been easy to omit anything emotional, and a struggle over the past few decades to relate what might appear as individual, and indeed internal to the brain, to social participation, identity, and activities. Humor by contrast, is unequivocally emotional, an attitude or orientation towards a situation; certainly the most salient examples of humor—jokes and comedies—involve at least a person and an audience.

On the other hand, although no one questions that humor has a cognitive aspect, the mental processes have not been very well articulated or formalized in models[8]. By Bartlett's (1932) theory of remembering, we might hypothesize that humor is pre-conceptual, a neuropsychological process for conceiving What-I-am-Doing-Now, with aspects that cannot (at first) be coherently related. Functionally, we could say this is the person's means of relating to an incomprehensible situation. In remembering (Clancey 1999, Chapter 8), the emotional attitude perhaps provides a basis for reconstructing (re-relating) previously active categories, such as in recalling the events of a story. In joking around, the humorous attitude may be a way of coming to terms with events that are inconsistent with past experience and hence otherwise irreconcilable (by the person's normative conceptual logic for organizing activities).

That is to say, in contrast with a folk view that humor is always a *reaction* to a situation (that has the inherent trait of being humorous), humorous experience may be an expression (action) of

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[8] An exception is Binsted and Richie (1997), which models humor as text manipulation using semantic networks, with some limited success in creating puns.

a disjuncture, a conceptual discoordination, an inability to conceive of what the situation is. By Bartlett's analysis, we must experience *something,* we cannot say with blank faces, "Does not compute." Instead, we chuckle, laugh, or giggle. For Tanner, the idea that "we are doing something all the time" is fully visible. (See Clancey 1997, Chapter 3 for related discussion.)

What I have provided so far is a neuropsychological sketch of humor; the social aspect is of course no less fundamental. Within an interpersonal activity, humor provides a way of handling conflict, which is to say that as each individual must experience something (handle a breakdown in some way), the group also must move its activity forward. So when the teacher asks Jen whether her graph helps one see how spread out the numbers are, she dips her forehead to the table and everyone laughs. As analyst-observers, we should always realize: The behavior could have been different. Jen might have said, "I don't know" or "I don't care." Her action instead could be interpreted as a submission, giving in to the teacher's instruction. Her attitude is open, she resolves the tension by playfully presenting she has nothing to say.

When the teacher asks Rachel (0315-59:15) where 300 would be on her graph, and adds "If there was a 300," everyone laughs. Perhaps something is happening off camera? Or the idea of a plant 300 inches tall is absurd? Or they adopt the teacher's remark as a means of resolving the tension of the moment? I do not mean to suggest that interpreting what is funny necessarily involves a simple, unique causal story. Indeed, an interesting hypothesis is that at first different individuals have different takes on what is occurring at a given moment, but most become caught up in the group's laughing, and *this* shared experience then orients the group's ongoing activity.

3.3 Purposeful context: A math activity within a plant experiment?

Seeing Tanner joking and listening to the discussion of "spread out," I often wondered how the students and teachers are conceiving of this classroom activity. I have argued that in the small

group Tanner is always in the activity of designing the graph, despite appearing to be only fooling around. But are the students ever in the activity of *doing a plant experiment*? Do they understand that the graphs are tools for conducting a broader inquiry?

3.3.1 Talk about properties of graphs

At the end of the third day (end of tape), the teacher says, "So would this graph help show you better—just the graph—how spread out it is?" Watching the tapes, this entire discussion seemed boring to me. How can we interpret the graphs without talking about growing plants? In the videos available to us, the described properties of the graphs are treated independently of the meaning of the numbers, which seems bizarre, given that the students actually came up with these numbers by measuring plants.

The numbers were first bastardized when the two experiments were clumped on March 13. The students appeared puzzled. Now they are just manipulating numbers. The idea of creating and comparing and presenting graphs is great, but then the inquiry has been moved from the plant domain—where graphs provide value because the numbers *have value*—to the graph domain—a list of numbers and a generalized property called "spread out." The teacher gives the impression that "spread out" is of interest for its own sake, and that tools for talking about "spread out" (the graphs) can be evaluated independently of the domain from which the numbers come.

There is nothing here about what the graphs are revealing about the plants. It is fine to abstractly try out different patterns (indeed, researchers analyzing data may explore charting options in a spreadsheet tool just to see what relations might be revealed). But then you say what you see in the graphs that relates to the phenomenon of interest. What does the graph reveal about plants growing under different conditions or different kinds of plants?

A comment in the facilitator-teacher notes from March 15 says "Students didn't carry over a lot from the rockets study last year." This is ironic given that the students are not being encouraged to "carry over" anything about *the plants* either. And if the rocket exercise was handled in a similar way, how could they make sense of these graphs any better? Indeed, with all of the debates about the nature of abstractions (e.g., Clancey 2001b), one might wonder whether abstractions would transfer better if they were contextualized in the first place.

One graph (0315 Presentation #5 by Greg, Kyle, and Katie of D19 exhibit) says "There are 47 different types of numbers used" and "How spread out are the height? 225" (which they show as the difference between the highest and lowest). Here we find two domains of analysis: properties of numbers and properties of heights. The discussion shows that the inquiry is not about plant heights, but about the shapes of graphs. Without a reference for "spread out" there is no evaluative criteria for the difference: Why should it matter how spread out a graph is and whether one graph shows it or not?

Plants do get mentioned, but only with respect to "what's typical," not motivating the question about plant growth that might be answered by understanding variability:

> 0315 Teacher: What about it helps you guys see that the numbers are spread and what a typical fast plant would be?
>
> Girl: To see how they're spread you have to look up at the highest one (points). And the lowest would be down here. You look to see how far out this way it is.
>
> 20:50 Teacher: Can you guys circle where a typical fast plant is?

Here the numbers are unmistakably interpreted as representing the height of individual plants. But this is an exception. The classroom exercise focuses on conveying properties of graphs, such as "a bell distribution"; thus it is said that using data from later in the plants' life would produce "a distribution that looks more normal." In contrast, inquiring about the plants, what can we say

about these plants on Day 19? How do various types of graphs help us understand the plants? Instead, the activity appears inverted, with the intention that graphing plant data will help us understand a bell curve! The focus is tool-centric as opposed to inquiry-centric. Rather than teaching about the nature of inquiry, the activity is teaching about the nature of graphs. What is the purpose of the exercise: Learning abstract math concepts ("spread out") or learning how to use graphing as a tool for doing science? Accomplishing both would make sense, but how could one omit the math as tool perspective?

3.3.2 Abstract layout talk vs. sketching and showing each other

A confounding issue is that the graph paper given to the students is for their final presentation; they can't write on it until they have created a design. Consequently, they perhaps waste time arguing in mid air, rather than sketching and showing design concepts to each other. Put another way, the presentation sheet is not a design tool, it must not be marked until the problem is solved. The problem this causes is painfully evident.

For example at 9:15 on March 13, they talk about where to start, 0 or 30? They could have simply started by sketching something and reflected on what it looks like? Kyle(?) says, "Plants start at zero," which is nice grounding in the experiment, but another student brings the group back to this set of numbers for D19, which starts at 30. Then Kyle agrees and says, "But where should we start?" referring to the big empty space of the sheet. We see many gestures along imaginary axes (would could be trivially sketched) (Figure 4).

Figure 4. 0313-10:59 "63 squares like this" (The graph page is blank)

Another group with three girls and Will are also gesturing to how to use the paper, what layout, what will fit, etc., all in words. Why don't they draw on another sheet and show a model of what have in mind? Why not use a ruler and show what will fit? Indeed, Julia(?) at 12:50, says, "Just draw it first!"

Another girl at 0313-12:22 says with exasperation, "That's what I'm saying!" Drawing might avoid all the verbal banter. Yet she hasn't even tried. The single large blank page appears to have caused their method to get stuck on "planning by talking." The tools provided shape the methods used. The graph sheet is like one big fill-in-the-blank test form. (Interestingly, Erica uses her own notebook in attempting to communicate ideas.)

3.3.3 Example of graphing as a tool for inquiry

To illustrate how the transactional aspect of graphing has been lost by viewing the graphs as having objective properties in isolation, I will present my own use of graphs for examining the classroom video.

In my experience, quantitative analysis is an essential part of ethnographic studies (Clancey 2001a; 2002). In particular, video data can often be fruitfully categorized by activities,

participant, location, and duration, leading to patterns that are not perceivable in the sequence of a transcript. For example, consider that some episodes appear to be relatively lengthy conversations between students without the teacher intervening. Also, I have implied that Tanner in some way dominates the graph presentation by his group. What are the frequencies and durations? Figure 5 provides a means of visualizing how Jessica, Tanner, Erica, and Kevin interacted with each other and the class when they stood at the front of the room.

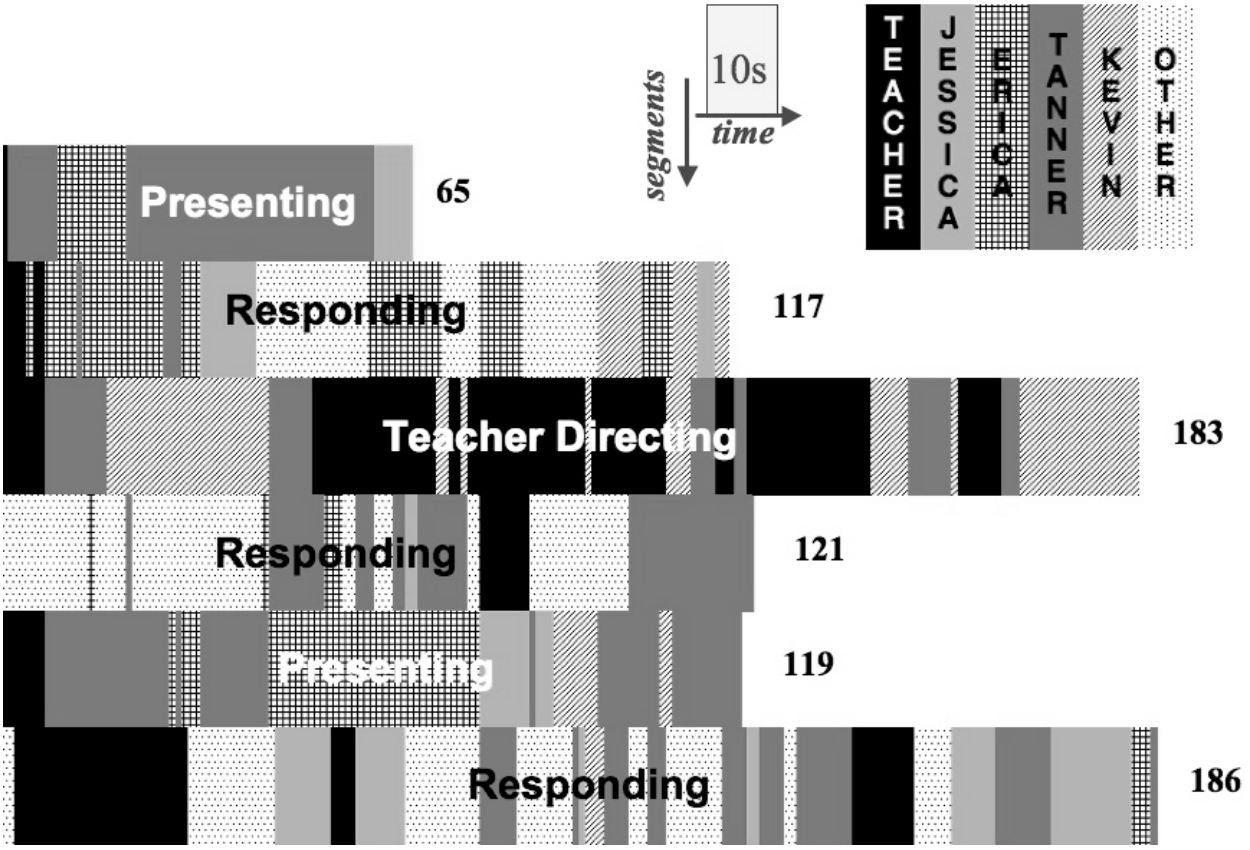

Figure 5. One group's graph presentation represented as six segments (from top to bottom), with speaking durations shown as colored bars. Duration of each segment on the right in seconds.

This graph depicts the entire episode when these four students were at the front of the room, including the teacher's remarks (in black) and other students' questions or comments (dots). I have chosen to view the overall episode as six periods in which the students were presenting the graph, responding to the teacher or other students, or in which the teacher was directing (the third

segment). In showing the episode in this way, one naturally questions the process by which it was created (you might want to look at the transcript corresponding to these segments to be sure you understand the categorization as representing the participants' understanding and whether you can see the alternation the graph claims). One also starts viewing the group's presentation through the graph. For example, we see that presenting the graph occurs twice, during about three minutes, which is about 25% of the total 13 minutes. This suggests a number of new questions: What affects the change between modes (presenting, responding, directing)? Who speaks with whom (is there a pattern of pairing)? Who speaks the most often? The longest during a turn? Who is relatively quiet? How do other groups compare? The graph presents the data so it can be perceptually grasped, revealing patterns (e.g., green and brown seem to appear together), leading us to ask numeric questions (how often is Tanner the one who replies to another student) and then pose new questions about relations (are the other students directing questions at Tanner or is he jumping in to answer questions?).

This example shows how a graph can be a tool for discovery, as part of an inquiry about the classroom. The graph provides a way to structure the available data, formalizing impressions (e.g. sometimes the teacher appears quiet for long periods) so they can be measured and thus compared. In my experience, creating one graph often leads to wanting another to view the data in another way. Figure 6 was an attempt to test my hypothesis that Tanner was speaking most often during the presentation.

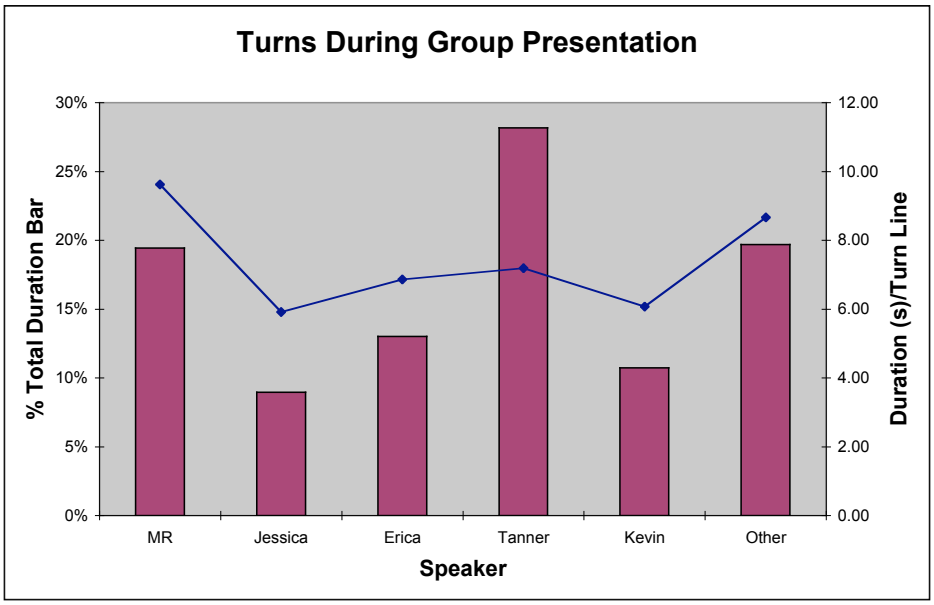

Figure 6. Participant turns during the group presentation. Bars indicate percent of total duration (e.g., Tanner was speaking more than 25% of the time); line indicates average duration of a speaking turn (e.g., Tanner's 7 seconds per turn was slightly longer than others in his group, but significantly less than the teacher or students in the classroom asking questions or making comments).

The graph surprised me by showing that Kevin spoke more than Jessica. Before seeing the graph, I would have said that Kevin was relatively quiet. So my impression was wrong. I have found in analyzing video that both analysts and participants can misjudge frequencies and durations of events.

These graphs illustrate the transactional perspective, as applied to teaching and learning, in two critical ways: in creating and sustaining the presentation's structure and in the nature of inquiry using a representational tool.

First, the segmentation suggests a pattern and episodic structure that no one in the classroom is strictly controlling, though they implicitly enable and contribute to its form. Individual behavior is constituted by the pattern (organized by it), just as individuals constitute the pattern

(confirming a phase by acting in a way that continues it, e.g., continuing to present the graph while the group is in presenting mode). Thus, the structure of the class's activity and what individuals do is mutual, both influence each other, both in historical form (being influenced by what has come before) and in forward effect (by serving to orient what participants can do next). So I am claiming that individuals conceive of the phases (What-We-are-Doing-Now) without naming them, necessarily viewing them consciously as being segments, or being aware of how they are alternating in a conceptually logical way (present-respond-direct-respond-present-respond).[9] However, it is reasonable to conjecture that the teacher is aware of redirecting the activity when he speaks, as I claim a more detailed content analysis would show in the development of the topics being discussed (i.e., I did not simply break the episode where the teacher speaks).

Second, the graph illustrates how representations (whether graphic or verbal) are instruments, as Dewey emphasized, as a means for carrying out an investigation. The graphs I present are not my summaries or codifications of "what happened," but my means for transforming the details of the transcript to a visualization with salient perceptual relations, to numeric questions that compare and contrast the individuals and groups, to hypotheses about why events occur when they do, to general conjectures for prescriptive experiments to improve the students' experience—quite a leap to be sure.

The transactional aspect of the graph is realized by not viewing it as a means of presentation of something already understood, already objectified. These graphs are not created to portray the

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[9] These are more or less familiar notions in *conversation analysis* (e.g., Sacks, 1984), though my attention to details in the transcripts is much less formal.

result of my inquiry, but are partly hypotheses, partly methods, partly summaries of how far I have gotten in my digging and shuffling and reorganizing of the available data. I use the graphs to convert the data into information through my perception, through computations, and through my poking around to find more patterns and connections. Thus my inquiry is a transactional relation between my looking, my transcribing, my selecting and commenting on excerpts, my graphing and inspecting of the graphs, and then my going back to reconsider the validity of my segmenting and its application to other groups. My actions in creating and formatting the graphs may be chronologically described, but relate to perceptions and concepts that have no fixed form. My intention to demonstrate an idea (e.g., showing that Tanner is dominating) produced an artifact with evident patterns that changed the direction of my thinking. And when I present the graph in a new setting, I may interpret its significance differently. My past experience with the graph will partly determine my using it in the future—just as I have imported these figures from my workshop presentation. But when I reuse such artifacts, I may attribute and articulate other values and properties that were only tacit or even non-existent in my original conception, creating a new view of these classroom episodes.

So here lies my ultimate objection to what I see in the classroom video: The graphs are presented as a final product, just as the graph paper was protected from experimentation, so a clean "result" could be put forth. The class is not inquiring about the plants by relating the graphs and asking what other graphs are now needed. They are myopically talking about the graphs as objects in their own right, removed from the plant-growing activity. Thus ironically, it appears that in this classroom the ideas of invention and presentation have been usefully applied, allowing the students to be creative and giving them the opportunity to address and respond to their classmates directly. But the idea of graphing, which is presumably the curriculum concept,

could have been given a much richer scientific or engineering context, and thus conveyed a far more general—and transferable—understanding of how to use graphs to make sense of experience to uncover useful patterns and processes. For example, what is learned about the plants could be related to practical concerns such as lighting and fertilizing plants (in my workshop presentation I used the example of designing greenhouses for Mars).

Accordingly, as should be obvious, I suggest that using graphs to analyze video quantitatively is essential for the scientific study of teaching and learning practices.

4. Conclusions

What does the transactional perspective, applied to a classroom video, suggest about "a program of studies for practice-based science of teaching and learning"? The research community has generally established that a great deal can be learned by studying classrooms (e.g., see *Journal of the Learning Sciences*). So really the question is focusing on the notion of *practice* and a *program* of studies. We have a handful of sub-questions here, with answers and approaches that I sketch in outline form:

1. **What is required to study practices (as opposed to isolated interactions, misconceptions, explanation, etc.)?**

   1.1. What's good about the data provided?

   1.1.1. Video has good close-ups, covers long periods (at least 30 minutes), tends to stay with people and conversations

   1.1.2. Photographs show materials relatively well

   1.1.3. A sequence of activities, constituting phases in an overall instructional activity, are recorded (creating and presenting graphs), i.e., the observations are systematic

1.2. How could it be improved?

1.2.1. Provide photographic/video overviews of the students' behavior, including grouping, movements, postures, and reactions (especially during the presentations)

1.2.2. Photograph all materials (e.g., Erica's personal drawings)

1.2.3. Provide a labeled diagram of classroom layout (and indicate how it changes)

1.2.4. Use two video cameras, one kept on wide-angle in a corner (e.g., during the 0315-28:40 discussion of the Stair Graph we can't see the students at all).

1.2.5. Time stamp all video and photographs (to measure durations of activities)

1.2.6. Aim video at people more frequently than artifacts (photograph static objects)

1.2.7. Don't omit phases in the broader activity (e.g., measuring plants, talking to other groups to understand their graphs)

1.2.8. Be more systematically comparative (follow two groups in creating graphs)

1.2.9. Take notes on the students' postures, overall tone of the room, sense of energy and progress, breakdowns (e.g., is the teacher missing something?)

1.2.10. Include post-class interviews (e.g., talk to students individually about what happened, video a roundtable feedback session, video-interview the teachers)

1.2.11. Give a written survey to the students after each session:

1.2.11.1. Define key concepts to detect changes (e.g., "spread out")

1.2.11.2. Ask what events in the class made a difference to student's understanding

1.2.11.3. "What would you have done differently if you had been teaching today's class?"

2. On what time and organizational scale does the notion of "educational practice" have meaning?

2.1. Is one class period ever sufficient? Or would we insist on following the class through several weeks or an entire quarter/semester?

2.2. Can we study this class apart from other classes in which the same players participate?

2.3. We might refer to the practice of the teacher, the class, the school—do we need to study the broader contexts to bring about change in individual class sessions?

3. What are we learning about what, where, and when learning occurs? In what sense is learning isolatable to particular events?

3.1. What's working in this classroom? What's not?

3.1.1. Good: They've created a representational world, an ecology of representations.

3.1.1.1. Graphed personally generated data in subgroups to answer questions about the numbers (typical + spread),

3.1.1.2. Presented another group's graph in partially student-managed sessions in which they discussed the generality of the graph, their properties independent of particular numbers, i.e., what if we had 555?

3.1.2. Good: The teacher orchestrates the discussions by engaging students, soliciting comments and questions, getting students to respond to each other, relating the work of different students, and moving the topic along.

3.1.3. Good: Enough students are responding often enough to make the discussions lively.

3.1.4. Bad: The focus is entirely on abstract properties of graphs (e.g., what they reveal about how spread out the numbers are), rather than what graphs reveal about the plant experiment. The idea of inquiry is impoverished at best.

3.1.5. Bad: The few times we see the rest of the class, most of the students appear bored and uninvolved, and few students express lack of understanding (e.g., Jen).

3.2. How do we know?

3.2.1. Facial expressions, posture, playful antics, laughter

3.2.2. Students responding directly to each other, students helping manage the conversation, frequency and duration of exchanges without the teacher speaking

3.2.3. Variation in graphs (including playful decorations) demonstrates freedom to be creative, to become engaged in the material (to be actually carrying out inquiry)

3.3. What is difficult to evaluate (requires further research)?

3.3.1. Whether it is good for a group to be strongly guided by a teacher, so at least one graph represents the textbook approach

3.3.2. Whether more students would be engaged if the graph exercise were clearly directed at understanding something about the plant experiment

3.3.3. Whether a single teacher is able to monitor and orchestrate given activities (e.g., facilitators could help interpret mumbled student remarks)

3.3.4. Individual differences in wanting or benefiting from guidance

3.3.5. What is learned at each stage: Measuring plants, graphing, understanding a graph, presenting a graph, participating in a graph presentation

3.3.6. Who's not involved and why

3.3.7. What is the pace/rhythm of conceptual change over multiple classes

3.3.7.1. Track use of vocabulary, participation/engagement, mimicking teacher's phrases and participation style

3.3.8. Importance of consistently and clearly expressing standards, evaluating alternatives, i.e., what's a good graph for this problem?

3.4. What could be easily changed if we provided appropriate feedback to the teachers?

3.4.1. Nature of facilitator-teacher guidance during graphing activity

3.4.2. Grounding the inquiry in the plant experiment

3.4.3. Clearer sense of where we are going with this graphing discussion (why should anyone care what a graph reveals about "spread out"?)

4. How is the transactional perspective useful for answering these questions?

4.1. Suggests designing learning activities as coherent *inquiry projects*, especially to ground science and mathematics in practical goals.

4.2. Reveals the perceptual work of understanding a representation, and how this may involve rotating the image, distinguishing notations from designs (figure from ground), and imagining transformations (inferring and applying the design).

4.3. Reveals that interpersonal experiences are co-determined, avoiding trait-style explanations of behavior.

4.3.1. Suggests analyzing a classroom episode as a performance by an *ensemble*, in which people are improvising, playing over and through each other.

4.3.2. Emphasizes how actions are *commentaries* that promote reconceptualizing (e.g., rechunking and relating) what has transpired (i.e., what are the events of the past) and what the past means going forward.

4.3.3. Suggests that these performances are *accomplishments* with implicit structure, that constrain individual actions and that is sustained and developed by them.

4.4. Reveals functional aspects of behavior that are ignored by theories that focus on properties and transformations of objects and people (e.g., as cognitive science studies of problem solving and instruction have not recognized the role of humor or emotion more generally in conceptual change).

4.5. More generally, supports a wholistic/systemic approach to understanding what is happening (the experienced events) and why—facilitates relating biological and social aspects of learning:

4.5.1. Include the conceptualized intangibles: Project, Activity (What I'm doing now), Attitude, Engagement/energy, Stage/Players/Experiences/Events, Persona

4.5.2. "Human factors": fatigue, hunger, postural discomfort, frustration

4.6. Encourages us to recognize the uniqueness of situations, the inability to strictly control learning or activities, more broadly. Guides us to view an activity design (or the curriculum more generally) as a guide/roadmap, not a fixed/optimal route or required path. Helps us to study each group diagnostically, emphatically, to understand its particular challenges, history, opportunities.

4.7. Provides an encompassing framework for composing research with everyday practical activity, making practitioners (teachers and students) into researchers for their own ends, and making researchers into participants, to understand how action influences the situations they are studying (and hence what are the practical opportunities for change)

5. If the point is to improve learning, can this be done apart from examining the community's objectives, that is, the purpose of school?

5.1. To what extent are communities focusing more on conserving the past (reproducing what is known) vs. preparing students for citizenship in the year 2025?

5.2. What are the problems we want a practice-based science of teaching and learning to solve? That is, what is the inquiry project in which we are engaged?

5.3. What are variations in answers to these questions across different regions of the USA?

5.3.1. What are the common problems, the opposed approaches?

5.3.2. Who are the stakeholders who should be involved in this research?

5.4. How should the research project be integrated with other activities and agencies within society to be productive?

The original charge for the workshop concerns "a practice-based science of teaching and learning." If we mean to be scientific, then we must understand—even as we analyze the experiences holistically—how the outcomes could have been different. For example, what is making a difference to students' learning in this classroom? What could be eliminated without much effect? What could be extended or emphasized to better effect? Personally generating the numbers from measurements? Graphing in subgroups? Understanding others' graphs? Presenting another graph? Standing up at the front of the room during the presentation? Leading the discussion? Seeing all of the graphs together at the front? Allowing every opportunity for individuals to express confusions?

It is difficult to imagine a claim that instructional design could be a science without specific hypotheses that certain aspects of an activity have predictable effects in certain situations. A transactional perspective doesn't rule out generalizations in the classroom any more than it ruled out generalizations in cell biology. One would expect at least rules of thumb for guiding discussions, and even activity toolkits that reliably produced energetic participation, questioning, and insights.

To conclude, I suggest that the following (at least) are required to develop a practice-based science of teaching and learning:

- Extensive observation and comparative analysis on different organizational scales (sessions, teachers, schools)—both repeating instructional activities like this graphing sequence and comparing with alternatives.
- Quantitative analyses of structure in classroom activities: Layouts, Phases, Rhythm, Participation.
- Theoretical broadening of biological and social aspects, such as the musicality of ensemble performances in work groups, the nature and function of humor, the growth of identity, and the many feedback relations of these dynamic processes: interpersonal regulation (articulation/co-construction) of norms, affective self-regulation, reflection and monitoring of progress, etc.
- Measurement of outcomes (defined goals and ways to assess results).
- Extensive participation by stakeholders, including conversations within the home communities on what this research might practically accomplish (not a choice among what is given, but alternatives the research will itself discover and create).

References

Bamberger, J. 1991. *The mind behind the musical ear*. Cambridge, MA: Harvard University Press.

Bartlett, F. C. [1932] 1977. *Remembering: A study in experimental and social psychology* (Reprinted). Cambridge: Cambridge University Press.

Bateson, G. 1972. *Steps to an Ecology of Mind*. New York: Ballentine Books.

Binsted, K. & Ritchie, G. 1997. Computational rules for punning riddles. *Humor* 10(1).

Revised: November 2004

Brown, J., Collins, S. & Duguid, P. 1989. Situated cognition and culture of learning. *Educational Researcher*, 18, pp 32-42.

Clancey, W. J. 1997a. The conceptual nature of knowledge, situations, and activity. In P. Feltovich, K. Ford, & R. Hoffman (Eds.), *Human and Machine Expertise in Context*, pp. 247–291. Menlo Park, CA: The AAAI Press.

Clancey, W. J. 1997b. *Situated Cognition: On Human Knowledge and Computer Representations*. NY: Cambridge University Press.

Clancey, W. J. 1999. *Conceptual Coordination: How the Mind Orders Experience in Time*. Hillsdale, NJ: Lawrence Erlbaum.

Clancey, W. J. 2001a. Field science ethnography: Methods for systematic observation on an arctic expedition. *Field Methods*, 13(3):223-243. August.

Clancey, W. J. 2001b. Is abstraction a kind of idea or how conceptualization works? *Cognitive Science Quarterly* **1**(3-4), 389-421. Special issue on abstraction.

Clancey, W. J. 2002. Simulating activities: Relating motives, deliberation, and attentive coordination. *Cognitive Systems Research*, 3(3) 471-499.

Clancey. W. J. in press a. Towards on-line services based on a holistic analysis of human activities. In P. Ritrovato and S. Cerri (Eds.), *Towards the learning GRID: Advances in human learning services*, Frontiers in Artificial Intelligence and Applications, IOS Press.

Clancey, W. J. in press b. Participant observation of a Mars surface habitat simulation. To appear in *Habitation*.

Clancey, W. J., Sachs, P., Sierhuis, M., and van Hoof, R. 1998. Brahms: Simulating practice for work systems design. *International Journal of Human-Computer Studies*, 49: 831-865.

Collins, A., Brown, J. S., and Newman, S. E. [1986] 1989. Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L.B. Resnick (ed), *Cognition and Instruction: Issues and Agendas.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Damasio, A. 1994. *Descartes' error: Emotion, reason, and the human brain*. New York: G. P. Putnam's Sons.

Dewey, J. 1938. *Logic: The Theory of Inquiry.* New York: Henry Holt & Co.

Dewey, J. 1958. *Experience and Nature*. In *Later Works*, 1: CD-ROM of *The Collected Works*.

Dewey, J. and Bentley, A. F. 1949. *Knowing and the Known*. Boston: The Beacon Press. (Online: http://www.aier.org/knowingandtheknown.html)

Garrison, J. 2001. An introduction to Dewey's theory of functional "Trans-Action": An alternative paradigm for activity theory. *Mind, Culture, and Activity*, 8, 275-296.

Glenn, P. 2003. *Laughter in Interaction*. Cambridge, UK: Cambridge University Press.

Lave, J. and Wenger, E. 1991. *Situated learning: Legitimate peripheral participation.* New York: Cambridge University Press.

Mulkay, M. 1988. *On Humor: Its nature and its place in modern society*. Cambridge, UK: Polity.

Provine, R. R. 2000. *Laughter*. New York: Penguin Books.

Sacks, H. 1984. Notes on methodology. In J. M. Atkinson and J. Heritage (eds.), *Structures of Social Action: Studies in Conversation Analysis* (pp. 21-27). Cambridge, UK: Cambridge University Press.

Schön, D. A. 1979. Generative metaphor: A perspective on problem-setting in social polity. In A. Ortony (Ed.) *Metaphor and Thought*, Cambridge: Cambridge University Press. pp. 254-283.

Schön, D. 1987. *Educating the reflective practitioner*. San Francisco: Jossey-Bass Publishers.

Revised: November 2004

Merriam-Webster 2002. *Webster's Third New International Dictionary, Unabridged*. http://unabridged.merriam-webster.com (22 Nov. 2004).

Wenger, E. 1998. *Communities of practice: Learning, meaning, and identity*. New York: Cambridge University Press.